

## UNROOFING OF PULMONARY TUBERCULOUS CAVITIES.

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A tuberculous cavity presents the most difficult problem in the cure of pulmonary tuberculosis. It may be compared to the cold abscess in Pott's disease, which, like the pulmonary cavity, can carry the case on to a fatal termination. A cold abscess in Pott's disease burrowing its way downward frequently continues as an active focus after the bone lesion has healed and can spread the disease to other bones and joints through direct contact with tuberculous pus. Such an abscess may rupture externally and terminate in mixed infection sinuses, which on account of their many pockets and ramifications, are so difficult to drain and heal. As a matter of fact, most of the fatal results in tuberculosis of the spine are due to cold abscesses terminating in amyloid disease, especially after mixed infection sinuses form, or end in arterial hypertension, nephritis and myocarditis as a result of slow toxemia due to absorption from the tuberculous abscess. Likewise, tuberculous cavities of the lungs, even after the lesions have become fibrous and are quiescent or arrested, can lead to additional new foci from aspiration of tuberculous pus along the bronchial tree; may give rise to fatal hemorrhages or may be the cause of amyloidosis or various organic diseases which follow the gradual and prolonged absorption of the contents of the cavity.

Statistics show that a large percentage (85 per cent according to Barnes<sup>1 2</sup>) of cavity cases die within the first two or three years and that practically all of the fatal cases of hemoptysis occur in patients with cavities.<sup>3</sup> Hemorrhages arising as a result of the ulceration of the bronchi or active inflammation of parenchymal foci are trivial affairs checking spontaneously and requiring little or no treatment, whereas the bleeding from cavities is apt to be copious and recurrent. Such hemorrhages may lead to asphyxiation if the patient is unable to readily clear the lungs of blood, or to fatal aspiration pneumonia when blood is aspirated into the lower parts of the lungs. Since the advent and development of roentgenology in the diagnosis

and study of pulmonary tuberculosis we have learned more to respect cavities and the study of the development and progress of cavities in X-ray films has impressed us with the necessity of devising methods of treatment for bringing about their obliteration. Roentgenology, by affording us a more accurate way of studying the development of pulmonary tuberculosis and by enabling us to follow up through serial films the pathology and pathological changes during the course of the disease, has increased our knowledge of pulmonary cavities and has taught us what type of cavity can be expected to heal spontaneously and what type will require some form of collapse therapy for obliteration.<sup>4</sup> Thin-walled cavities in the subclavicular or mid lung can heal spontaneously under carefully applied hygienic treatment. If the surrounding lung is considerably involved or if the cavity has a thick wall and the parenchyma adjoining the cavity has lost its elasticity through fibrosis or tuberculous infiltration, the chances of healing spontaneously are very slight. Likewise, old subpleural cavities at or near the apex rarely close without some form of collapse therapy. Cavities may heal spontaneously within a few months or they can heal very slowly spontaneously, requiring a period of years for closure. In the meantime, hemorrhage or aspiration may change the whole clinical aspect of the case.

The presence of tubercle bacilli in the sputum over a prolonged period as a rule indicates cavitation and the very presence of tubercle bacilli in the sputum increases the chances of various tuberculous complications such as tuberculosis of the intestines and tuberculosis in other parts of the body. In addition to the above, I might mention the great danger of cavity cases in the midst of a family, especially where there are children. These cases are frequently in good general condition and being ambulatory, go about freely, spreading their bacilli far and wide. This is an added reason, and important one, why every effort should be made to close tuberculous cavities. It is very difficult to impress patients with the importance and necessity of undergoing some form of chest surgery for the collapse of cavities, especially if the individual is up and around and in a fairly good state of health. It is not easy to make the sick man himself or members of his family understand that cavities are a source of great danger and that they stand between the patient and recovery until

gotten rid of. They prefer to drift along without immediately risking their life in the hope of eventually healing their cavities. The cavity, like the cold abscess, acquires a mixed infection as soon as it establishes a communication with a bronchus and besides swarming with tubercle bacilli, the cavity wall and contents harbor many other germs ever present in the respiratory tract.

Absorption from open cavities depends upon the number, size, location, drainage and character of the mixed infection present. During periods of poor drainage, the patient may have chills, sweats, increased elevation of temperature and various other symptoms of toxemia and these symptoms abate as soon as drainage is re-established and the contents of the cavity freely emptied.

Too frequently doctors are misled by the good general appearance of the patient, by the mildness of symptoms and the absence of physical signs of cavity and assume that a cavity does not exist. The patient drifts along with a false feeling of security until one of the complications develops. Then it is frequently too late to employ any of the methods of collapsing the lung. Much of the confusion regarding the frequency and fatal prognosis of cavities is due to the fact that most of them are silent and can only be demonstrated by means of the X-ray. This fact is becoming more generally known and most physicians require the use of the X-ray for diagnosis before passing on the existence, character and prognosis of pulmonary tuberculosis. While under treatment it is becoming more customary to have X-ray plates taken from time to time in order to determine accurately the progress of the disease. It is believed that the majority of physicians realize the importance of this practice and therefore a better knowledge of the behavior of cavities is being obtained. It doesn't take much experience in the treating of cases where X-rays are made routinely to emphasize the importance of making every effort to close pulmonary cavities. Roentgenology has also taught us that cavities are not completely obliterated by thoracoplasty.

There are various ways of eradicating cavities. Certain types can be expected to heal spontaneously if, as mentioned previously, the cavity is thin-walled and surrounded by a normal or very little involved lung parenchyma; such cavities are usually seen in the infraclavicular region or the mid lung. Thick-walled cavities, multi-

locular cavities, cavities at the apex, or to a lesser degree cavities at the base, cannot be expected to heal spontaneously. A carefully applied sanatorium regime of rest in bed and fresh air may often bring about the rapid healing of the type recognized as amenable to this form of treatment. Those which do not heal spontaneously must be treated by some form of collapse therapy and artificial pneumothorax is the method of first choice. We make it a rule at this hospital to apply artificial pneumothorax if the patient is a young adult and his pulmonary lesions show cavitation, even though there may be some involvement in the better lung. If a cavity is present in older patients, that is, those who are over thirty-five, and the cavity is of a favorable type for spontaneous closure, a period of observation for one month is allowed to elapse before the question of collapse therapy is finally decided. During this time the patient is kept at absolute rest in bed. If, at the end of that period the cavity displays signs of closing and the lesions show evidence of clearing, further expectant treatment is employed to permit the cavity to heal spontaneously, if possible. As soon as any evidence of retrogression occurs or any complications arise, or as soon as it is apparent that the cavity will not close within a reasonable time, collapse therapy is recommended at once.

Frequently cavities cannot be healed under artificial pneumothorax due to the presence of pleural adhesions. At times these adhesions may be broken up or stretched and the cavity terminated by means of slowly and gradually increasing the air pressure. In such cases, where considerable time has been required to close a cavity by means of pneumothorax therapy, the continuance of pneumothorax must be prolonged. Not infrequently when such lungs are permitted to re-expand the cavity reopens. These patients must often be kept under pneumothorax compression for three years or even longer and then when allowed to re-expand must be checked up frequently by means of roentgenograms before the lung is finally allowed to come in contact with the parietal pleura. Phrenicectomy as an adjunct to artificial pneumothorax is valuable in the ultimate cure of tuberculosis. It elevates the diaphragm, relaxing the lung still more, enabling the obliteration of cavities even though adhesions are present.

Adhesions preventing the collapse can at times be separated by

either open or closed pneumolysis. The closed method is to be preferred, especially if the operation is entrusted to skilled and experienced operators. In such cases, if the operation is successful, the pneumothorax should be prolonged as there is a greater danger of recurrency after re-expansion takes place.

The next method of obliterating cavities is phrenicectomy, to be chosen second to pneumothorax because it is a simple procedure and has few complications. Phrenicectomy gives the best results in types of cavities amenable to hygienic treatment, that is, types which belong to the class that can be expected to close spontaneously. In addition to this type of cavity those at the base, which usually will not heal spontaneously, are very amenable to phrenicectomy. Cavities surrounded by fibrosis and cavities located at the apex of the lung as a rule cannot be affected by phrenicectomy. Exceptions to this rule have been observed, but such exceptions are rare. The results from phrenicectomy are usually more permanent than those of pneumothorax, which may be due to the present practice of discontinuing pneumothorax after  $1\frac{1}{2}$  years.

Not infrequently we are forced to resort to thoracoplasty in the healing of cavities. In recent years many cases have been treated by this method and excellent results often obtained. However, experience has shown us that there are certain objections or drawbacks to thoracoplasty. The principal ones are as follows: first, thoracoplasty is a major operation sure to be associated with a certain operative mortality and by various complications following the operation; second, in order to employ thoracoplasty in the obliteration of cavities it is necessary to permanently put out of use a certain amount of normal lung parenchyma which throws a greater load on the contralateral lung. As pointed out in a previous paper<sup>5</sup> thoracoplasty, if possible, should be limited to a resection of the upper five or six ribs. Upper stage thoracoplasty collapses the part of the lung usually advancedly involved and the part where cavities are located most frequently and show the least tendency to heal spontaneously. Lesions or cavities in the lower part of the lung can generally be healed by means of pneumothorax or phrenicectomy, if necessary, in connection with an upper stage thoracoplasty. The advisability of limiting our thoracoplasties to the upper stage is that the operation or some modifica-

tion accomplishes all that is desired and leads to no deformity of the chest. In addition, it sacrifices very little normal pulmonary parenchyma and only a part of one lung is permanently eliminated. The lower part of the lung, if involved, can be taken care of by less drastic means. The resection of ribs is limited to an area of the chest covered and supported by the scapulae, so that later no dyspnea and rapid heart action result from paradoxical breathing. In returning Army personnel to duty, it is necessary that they have more than one lung intact or they are physically disqualified. It has, therefore, been our endeavor to limit our resections to the upper ribs, having in mind the cavity obliteration and arrested tuberculosis with as little deformity and loss of lung as possible, so as to qualify the patient for full military duty.

Returning to the treatment of cavities by means of thoracoplasty, we might say that the principal objection is third, cavities cannot always be completely obliterated by thoracoplasty. This is not only true of the giant cavities, but even medium sized ones, particularly those which lie posteriorly in the paravertebral groove, escape obliteration. The paravertebral groove, protected by the lateral processes of the spine, is little affected by resection of the ribs, and a cavity located in the part of lung occupying this section of the thorax is only slightly compressed by thoracoplasty. A cavity may also be crowded backward into this space and escape collapse. After much experience and careful study of operated cases, it is now beginning to dawn upon the chest surgeon and those treating thoracoplasty patients that thoracoplasty frequently fails to completely obliterate cavities and the patient continues to have symptoms of tuberculosis, including a positive sputum. More acute symptoms may arise from time to time caused by mixed infections and interference with drainage. Experience has shown that cavities in the lower part of the chest can be obliterated by merely relaxing the lung parenchyma as witnessed by the closure of basal cavities after phrenicectomy or following a lower stage thoracoplasty, which produces only partial compression of the lung. The direct opposite is true of cavities in the upper part of the lung. Here the compression must be sufficient to completely approximate the cavity walls before healing will occur. If the immediate results of the operation show only partial compression

of the cavity, further shrinkage seldom occurs; on the contrary, cavities may be expected to enlarge, especially if the operation interferes with its drainage. While thoracoplasty reduces the size of the chest, it also converts it into a rigid cage inside which the partially collapsed lung has no opportunity for further shrinkage. When thoracoplasty fails to materially reduce the dimensions of a cavity, it has been the practice to reoperate the case, performing a new thoracoplasty superimposed on the old one. Such an operation is difficult and dangerous on account of the time consuming and intricate resection of rib bridgings, greater bleeding and increased shock. Reoperations are seldom successful and effective in greatly reducing the size of the cavity. We have seen cases made worse by thoracoplasty when the cavity was only partly compressed. Even the most radical type of thoracoplasty, that is, one in which the technique of the operation requires complete removal of the first rib and a wide subscapular resection of the upper five ribs, frequently fails to complete the obliteration of the cavity. In the employment of additional operations such as secondary lateral thoracoplasty,<sup>10</sup> where the remainder of the upper five ribs is removed, failure to obliterate cavities is encountered due to the fact that it is impossible to completely compress the lung which lies in the paravertebral groove and which is frequently the site of cavities or into which the cavity is displaced after thoracoplasty. Cavities in the upper part of the lung which fail to close after thoracoplasty often enlarge, as previously stated, and may cause late complications due to poor drainage or due to mixed infection frequently following some intercurrent respiratory disease. We have observed cases of thoracoplasty which improved markedly following operation and which apparently recovered their normal degree of health, but which became worse following influenza or one of the usual respiratory infections caused by a mixed infection in the cavity only partially collapsed. Due to such reinfections paroxysms of fever occur from time to time when the cavity fails to drain properly. Another complication arising from cavities incompletely obliterated by thoracoplasty is hemoptysis, and the origin of the hemoptysis is almost invariably a cavity in the collapsed part of the lung which has not been successfully compressed.

We still have other means of obliterating cavities. One of the

more recent methods and one now being used more frequently is external pneumolysis or apicolysis. This procedure consists in stripping the lung from the chest wall over the site of the cavity and packing the extrapleural pocket, thereby formed, with gauze or with paraffin. Pneumolysis may be employed in connection with thoracoplasty. Especially in the giant forms of cavities the combination of anterior pneumolysis and posterior thoracoplasty is to be recommended and this combination succeeds, as a rule, in obliterating completely even the largest cavities. In cases with giant cavities in which a collapse of the cavity is imperative and in which the general condition of the patient makes a thoracoplasty a grave risk, it used to be our policy to do a preliminary phrenicectomy and follow this with a pneumolysis, resecting a portion of the second rib in front, stripping the lung from the chest wall over the extent of the cavity and packing the extrapleural pocket with vaseline gauze containing a small percentage of iodoform and bismuth. After the pneumolysis pocket is well on its way to healing, posterior upper stage, five ribs, thoracoplasty is performed. This combination of operations will usually obliterate upper lobe cavities, even though huge and occupying most of the upper part of the lung. At times when thoracoplasty fails to obliterate the cavity a pneumolysis is performed over the site of the cavity posteriorly and a paraffin pack inserted. Paraffin packs are at least temporarily successful, especially when inserted posteriorly in the interscapular space, but have the same disadvantage of thoracoplasty, inasmuch as they do not always completely close the cavity. Great care and skill have to be exercised to make sure that the parietal pleura over the extent of the cavity is completely uncovered or that the extrapleural cavity more than approximates the extent of the pulmonary cavity and that the pack is inserted firmly so that the pulmonary cavity is completely closed. This procedure may lead to a rupture into the pulmonary cavity, which then has to be treated by means of unroofing. It has been our experience that paraffin packs have to be removed eventually on account of irritation and infection, but by this time the cavity may be healed and the purpose of the pack terminated.

Another, and in some ways our surest, method of obliterating cavities is unroofing. This method suggested itself to us through



complications of other methods which proved successful in the end. One patient with a giant cavity occupying most of the upper lobe of the lung was subjected to a pneumolysis in which the extrapleural space over the cavity was filled with vaseline gauze and in which the pulmonary cavity finally ruptured into the extrapleural pocket. This patient was then given a posterior upper stage thoracoplasty. A deep-seated infection occurred in the thoracoplastic wound and the thoracoplasty was finally opened for drainage. This complication led to the formation of a sinus so that the pulmonary cavity was drained from the front and behind. After the infection was finally eradicated and healing with fibrosis occurred, the cavity was completely obliterated. The patient today is in excellent health, but still has a small sinus in front leading down to the site of the cavity, which is at the opening of a large bronchus and which still has some mucopurulent drainage due to a bronchial fistula.

Another case of external pneumolysis and paraffin pack developed infection around the pack six months after operation and when the wound was opened and paraffin pack removed we discovered that the cavity had ruptured into the paraffin bed. The opening to the cavity was enlarged and the entire wound, including the paraffin bed and the cavity was packed with iodoform gauze. This patient had an uneventful convalescence and finally completely recovered from tuberculosis.

Very few cases of unroofing of cavities have been published in medical literature. Lilienthal reported several cases<sup>9</sup> and in 1924 Gekler and his associates published three cases where tuberculous cavities were drained.<sup>6</sup> They came to the conclusion that the operation was safe, associated with very little shock and was practical. Sauerbruch discusses it to a limited extent in his book on chest surgery,<sup>6</sup> giving briefly the indications for the operation, the technique and the results to be expected. It is to be assumed that unroofing of cavities is not being employed on a large scale and has apparently been considered impractical by most chest surgeons.

Following the frequent failure of closing cavities completely by thoracoplasty and pneumolysis it was decided to introduce the operation in this hospital, depending upon heliotherapy applied directly to the inner walls of the cavity to bring about ultimate healing. Unroofing of cavities is, therefore, indicated where

other methods fail to bring about their obliteration. Residual cavities following thoracoplasty or following pneumolysis can be treated by unroofing. In cases of severe recurring hemoptysis, unroofing is also indicated when the source of the bleeding can be definitely determined and the patient is not too far advanced, so that the operation will be worth while. Cavities in the mid lung are particularly suitable for this operation after pneumothorax and phrenicectomy have failed. Such cavities can only be eliminated by means of thoracoplasty by performing the more radical type of thoracoplasty and sacrificing one whole lung. We see cases now and then in which there is a single cavity in the region of the hilum of the lung paravertebrally and the remainder of the lung shows little if any involvement; there may be some involvement in the contralateral lung. We would hesitate in such a case to sacrifice one whole lung in order to bring about the closure of a cavity. Such cavities can be unroofed with very little damage to the surrounding lung. They usually heal and close fairly rapidly after the operation, leaving behind, however, a bronchial fistula. It would seem especially desirable to resort to unroofing cavities where there is considerable involvement of the good lung or where the cavities are bilateral and it is necessary to use some form of collapse therapy on both sides in order to save the life of the patient. Not infrequently after an unroofing operation a cavity in the unoperated side heals spontaneously. Following thoracoplasty, the operation is used to complete the closure of the cavity. In such cases, of course, the upper part of the chest is already collapsed. Unless very large, cavities heal slowly but surely after they have been unroofed. In secondary unroofing it is necessary to remove the bridges between the cut ends of the ribs resulting from the first operation. This causes a further collapse of the upper part of the thorax before the cavity is unroofed. In large upper lobe cavities it is also advisable to perform a posterior thoracoplasty prior to and at the time of the unroofing operation. Where it is necessary to unroof and pack a cavity in order to check severe and repeated hemorrhages, a local anesthesia frequently has to be used in order to avoid aspiration of blood during the operation. In using this method to check hemorrhages we have erred on the conservative side. After aspiration occurs and pneumonia develops it is too late to resort to surgery. In several cases I feel that the patient would have been alive

today if the cavity had been unroofed after the first hemorrhage as soon as it was discovered where the hemorrhage was coming from. In several instances we have waited, hoping the hemorrhage would not recur and have had our patients develop aspiration pneumonia with the next bleeding.

The technique of the operation for unroofing cavities is not involved or dangerous. The operation can be performed with very little shock and with few complications. Experience has taught us that these complications are to a great extent avoidable. The operation is performed the same as the posterior thoracoplasty, resecting enough ribs to cover the extent of the cavity. After the ribs are removed the intercostal muscles are resected off of the parietal pleura and the skin margins are sutured to the cut edges of the interscapular muscles and extra pleural fascia. After this is accomplished, the surgeon locates the cavity. This is easily done, especially as the cavity is subpleural as a rule and can be located by feeling the lesser resistance over the site of the cavity. The parietal pleura and lung overlying the cavity is first coagulated by means of the electric cautery needle, using a coagulation current. This is done along the margins of the cavity and is followed by the opening of the cavity by means of the electric cautery knife. A Bovie electrical unit is highly recommended for electrocauterization. The cavity should be opened widely because it is necessary in the after treatment that it drain completely and that the entire surface of its wall be exposed to the rays of the sun. As soon as the cavity is opened it is tightly packed with argyrol or iodoform gauze and the wound left widely open, except perhaps the upper and lower margins which do not lie over the cavity opening and which can be sutured. The skin and muscles are tucked in and sutured into the bottom of the wound. The chest is tightly strapped as following thoracoplasty and the patient returned to the ward. The following day the straps are removed and the pack changed. This procedure is repeated daily. If iodoform is employed as a pack, it may have to be discontinued after a few days, depending upon the tolerance of the patient. Ten per cent argyrol gauze or gauze saturated with 1-1000 solution of bismuth violet in five per cent alcohol solution may be substituted. The severity of the mixed infection depends usually on the nature of

the bacteria present in the cavity at the time of operation. In addition to 10 per cent argyrol, one of the various aniline dyes can also be employed to keep the cavity and surrounding wound clean, among which bismuth violet (1-1000 solution in 5-10 per cent alcohol) is to be highly recommended. After five or ten days the patient is given heliotherapy. The patient is moved onto the sun porch and the wound opening exposed to the sun, changing the position of the patient so that the sun shines directly into the cavity and shifting the position from time to time so that the entire inner wall of the cavity is covered. Exposure is first for five minutes, increasing five minutes a day up to one-half to one hour. Care should be exercised so that only the part of the chest at the site of the wound is exposed. From time to time the inner wall of the cavity may have to be touched up with a dye solution, either painting the entire inner wall of the cavity, the parts that show sloughs and more severe inflammation. At the time the cavity is opened its walls are invariably lined with a pyogenic membrane, caseated tuberculous tissue and sloughs, and is usually bathed in pus. The cavity may be multilocular, in which case all the trabecula and partitions should be removed, converting the area into one large cavity. When more than one cavity is present, the chest opening should be enlarged so that both are uncovered by the same wound. A short time after light therapy is started, the membrane clears from the wall of the cavity and healthy bleeding granulation tissue takes its place which goes on to scar tissue formation, contraction and ultimate obliteration of the cavity, sinus and wound. This is a rather slow process towards the end and the length of time required for recovery depends upon the size of cavity, character of mixed infections present and whether or not thoracoplasty has been used as a preliminary to the unroofing, that is, on the amount of collapse of the bony thorax.

Another factor which delays the closure of cavities is the presence of bronchial fistulae. As a rule, one or more bronchial fistulae can be seen entering the cavity and the hissing or squeaking sound made by air forced out of the fistula can be heard. If these fistulae are small they heal along with the closure of the cavity, but if large, some additional measures must be employed to further their contraction such as touching the opening of the fistula with 50 per cent silver nitrate solution. The applicator should be small enough to

permit entering the bronchial lumen a short way. Another method to be tried in the closing of fistulae is the electric cautery, using the coagulation electrode and current and puncturing the lung around the fistula. This produces scar formation, the contraction of which may close the opening in the bronchus. A purse string suture around the fistula can be used, if there is sufficient redundant fascia and scar tissue present, or some form of plastic surgery such as suturing fascia lung tissue or muscle over the opening of the fistula. Dakin's solution cannot be used in the sterilization of these cavities on account of the presence of fistula and we must use iodoform gauze and packs of 10 per cent argyrol gauze, aniline dyes or heliotherapy for this purpose. Probably one of the most troublesome and serious common complications in the unroofing of cavities is wound infection. As soon as the cavity is unroofed, the thoracoplasty wound is bathed in cavity pus swarming with all kinds of bacteria, including tubercle bacilli. This infection creeps into clefts of the fascia, between the bone and periosteum of the resected ribs or is carried into open lymphatics and vessels, resulting at times in sapraemia, septicaemia, abscesses and sloughing. Antiseptic dressings and heliotherapy may take care of this condition, but not always. In one case, the infection from the cavity content proved to be a streptococcus haemolyticus, which invaded the blood stream and terminated in death from a streptococcus meningitis. To avoid this complication, whenever possible, we are now performing the unroofing operation in two stages. First, a preliminary thoracoplasty clearing the parietal pleura of intercostal muscle and fascia, suturing the wound margins over the rib endings and packing the wound with argyrol or iodoform gauze. The chest is strapped tightly as in thoracoplasty and after a few weeks when the wound is healed, except over the part occupied by the cavity, the second stage is performed, consisting in unroofing the cavity with the electro-cautery, evacuation of the contents of the cavity and packing with iodoform or argyrol gauze. Since this procedure has been adopted, wound infections have been mild and less troublesome.

A hemorrhage into the unroofing wound of a cavity communicating with a bronchus must always be taken seriously on account of aspiration. This complication is to be guarded against. One of our

cases died of aspiration pneumonia and another of asphyxiation in consequence of wound hemorrhages. Such hemorrhages can be prevented by firm packing at all times and once they occur by the usual methods of hemostasis.

Unroofed cavities ordinarily heal slowly but surely. Care has to be exercised to prevent too rapid healing on the surface lest after closure a cavity remains around the opening of the bronchial fistulae. This is especially apt to occur if the bronchial fistula fails to close and if heliotherapy is used. Frequently these cases have to be re-operated and the external wound enlarged. Further plastic surgery such as a lateral thoracoplasty through the axillae may be indicated to increase the collapse of the bony thorax, to aid the closure of the cavity and bronchial fistula.

According to our experience so far, wound infection and hemorrhage can be minimized and dealt with successfully as complications, but bronchial fistulae still remain as a disadvantage in the unroofing of cavities. Until further experience has taught us more regarding the closure of bronchial fistulae, they will continue to be troublesome. They, no doubt, retard the healing of the wound and mar the results in the unroofing of pulmonary cavities. They offer a certain degree of danger from aspiration and the patient objects to their presence and persistence. A certain percentage resist all efforts at closure. Graham<sup>8</sup> reports 45 cases of cautery phrenicectomy, 31 or 69 per cent of which became symptom-free, with 10 or 35 per cent having persistent bronchial fistulae. Largely as the result of this difficulty in preventing and treating bronchial fistulae complicating unroofing cases, some other method of performing thoracoplasties with the object of assuring the complete closure of cavities was considered, and finally Colonel Casper, Chief of the Surgical Service at this hospital, devised a combination of posterior upper stage thoracoplasty and external pneumolysis, which has proven to be both practical and effective.

The technique of this operation was suggested in the course of the first stage procedure for the drainage of a tuberculous cavity of the upper lobe, as previously mentioned. It had been found that it is best to do a two stage operation for the drainage of these cavities. First, an extrapleural thoracoplasty is done and the wound packed

open. When granulation is sufficiently advanced, the rib ends covered, and all pockets filled, the cavity is then opened and drained without danger of serious wound infection. The disadvantages of cavity drainage are evident, granulation and filling in are slow, bronchial fistulae are inevitable and the final closing of the fistulae problematical. It seemed that, if the open thoracoplasty wound were packed firmly enough, the cavity might be obliterated and subsequent drainage made unnecessary. Also about this time a former patient returned to the hospital who had had a thoracoplasty some years previously. There had been infection in the wound which had opened widely and packed. The end result was excellent, a large cavity having been completely obliterated. This, too, suggested the idea that firm packing of the wound might not be a disadvantage. With these cases in mind, a technique was planned, designed to close any apical tuberculous cavity of any size and in any location. The first stage is an upper stage extrapleural thoracoplasty, removing wide sections of five to seven upper ribs, depending upon the location of the cavity. This part of the procedure is well known and requires no further description. One point, however, requires emphasis and that is that every possible portion of the periosteum be removed from the ribs and left in the wound. The reason for this will appear later. The next step is an extrapleural pneumolysis, the parietal pleura being stripped from the spine and from the dome of the thorax. This procedure is most easily begun by following the posterior rib stumps, separation of the pleura being carried out by the finger hugging the bone closely. This separation is usually easy, and can be carried as far forward on the spine as the indication of the case requires. Occasionally the pleura is so adherent that a periosteal elevator must be employed to start the separation.

Starting from each rib stump the separation is continued above, below and forward, the fingers meeting on the spine anteriorly to the intercostal muscles. Where extreme collapse is desired, these muscles must be divided between the ligatures close to the spine as stretching across the space to be collapsed they prevent complete approximation of the posterior parietal pleura to the anterior chest wall. The pneumolysis is continued over the apex of the lung. However, it is not desirable to carry separation too far anteriorly lest a thick-walled

cavity be displaced downward rather than collapsed by pressure from behind against the anterior chest wall. Packing is now applied so that the lung is compressed against the anterior chest wall. Roller bandages soaked in 20 per cent argyrol are used for this purpose and it usually requires three 3-inch bandages to provide sufficient packing. The cut edges of the back muscles are closed in with double sutures of catgut, approximating the superficial and deep layers of fascia and likewise providing for hemostasis. The forward curving lower end of the incision is closed by sutures, the paravertebral portion being left open and its edges packed apart. The same type of adhesive plaster dressing is applied as in the ordinary thoracoplasty. The outside dressing is changed in twenty-four or forty-eight hours, depending upon soiling, but the packing of the deeper wound is not disturbed for five to seven days. Thereafter the wound is dressed and the packing removed and replaced every two or three days. The wound is tightly packed until periosteal regeneration has so far advanced that the bottom of the wound is rigid; in other words, until a rigid bony thorax has resulted. This is of great importance to the patient, and for this reason all possible periosteum is preserved. After that packing is put in lightly, and granulation or filling in of the wound is encouraged. Complete healing may be expected in about three months. Long before that time, however, the patient may be ambulant. It is surprising how little the patient complains about the discomfort of the dressings. After the first ten days, there is hardly any complaint at all.

While a linear scar is hardly to be expected, the end result is surprisingly inconspicuous. The function of the shoulder and arm is entirely regained before the wound is healed. The disadvantages of this procedure are: length of time required for healing, the number of dressings necessary and the depressed and broad scar which often results. In compensation for these disadvantages, however, the patient may be promised that his cavity will be closed, which the standard procedure fails to do in about 50 per cent of the cases. Infection need no longer be feared. The type of dressings prevents mediastinal flutter and pendulum breathing. Patients have less shock and a more smooth convalescence than with an ordinary extrapleural thoracoplasty.



## STATISTICS.

The following statistics are based on all unroofing operations for the obliteration of tuberculous pulmonary cavities and include pneumolysis cases or combinations of posterior thoracoplasty and pneumolysis. The high mortality rate in the unroofing cases can be attributed to the fact that most of these patients had advanced lesions in both lungs; had serious complications and were operated upon with uncertainty of result and outcome in the hopes that surgery might perchance prolong or prevent a fatal termination. Then again, the operation was new and in the experimental stage so that we were unprepared to prevent and deal with complications in a manner which comes with experience. We are convinced that the complications responsible for many of the deaths can be prevented or successfully treated in future practice. Fatal outcome will continue to occur, however, because the unroofing of cavities cannot always be expected to check the advance of the tuberculosis in the type of case forced to seek relief from surgery. It is also believed that some improved method will be devised for the rapid closure of bronchial fistulae and that many of our cases will in time, as healing progresses, further close their fistulae. Now that we feel sure that the Casper method of performing thoracoplasties will prove more successful in treating cavities, the unroofing operation will not have to be resorted to so frequently.

UNROOFING OF CAVITIES, PNEUMOLYSIS AND CASPER  
OPERATION CASES.

Result of Operation	Unroofing of Cavity—22	Thoracoplasty and Pneumolysis—12	Pneumol- ysis—4	Casper Operation—10
Apparently cured . . . .	0	0	0	0*
Arrested . . . .	3 (13.63%)	3	0	0*
Improved . . . .	9 (40.9%)	5	3	10
Unimproved . . . .	1 (4.6%)	1	0	0
Died . . . .	9 (40.9%)	3	1	0

\*Too soon after operation for higher rating.

## TWENTY-TWO CASES OF UNROOFING OF CAVITIES.

Nine deaths as follows: hemorrhage (aspiration) 3; hemorrhage (loss of blood) 1; failure to check advance of disease 3; amyloidosis 1; streptococcus septicemia 1.

Reason for operation: to obliterate cavity 19; to treat hemorrhage 3. All

cases developed bronchial fistulae and with one exception none have closed completely; a number have obliterated their cavity and four of these have now fine external fistulae which close and open again from time to time.

#### TWELVE CASES OF THORACOPLASTY AND PNEUMOLYSIS.

Three deaths: 2 due to shock and 1 to tuberculous meningitis. In the latter case patient closed large cavity in contralateral lung and was considered an arrested case but died later of tuberculous meningitis.

#### FOUR CASES OF PNEUMOLYSIS.

One death due to tuberculous meningitis and failure to check advance of disease.

#### TWELVE CASES OF CASPER TECHNIQUE.

In all cases cavities have been obliterated. These cases have been free of complications.

#### SUMMARY.

1. The greatest problem in the treatment of chronic pulmonary tuberculosis is the obliteration of cavities.
2. A certain percentage of tuberculous pulmonary cavities heal spontaneously under carefully applied hygienic treatment.
3. Others remain unclosed in spite of rest, fresh air and a nutritious diet, preventing recovery in the treatment of pulmonary tuberculosis. Open cavities are the principal cause of complications, extensions and exacerbations in pulmonary tuberculosis, serious hemorrhages and visceral degeneration.
4. Collapse therapy, including artificial pneumothorax, phrenicectomy, thoracoplasty and pneumolysis separately or in combination, together with a well-applied sanatorium regime, is the treatment applied at the present time for the healing of tuberculous pulmonary cavities.
5. After other methods of collapse therapy have failed, thoracoplasty is our means of healing cavities. Those in the lower part of the lung can be obliterated by a lower stage thoracoplasty, which merely produces a partial collapse of the lower part of the lung, but cavities at the apex or upper part require a close approximation of the cavity walls for obliteration.
6. Incomplete closure of a cavity fails in many cases to rid the sputum of tubercle bacilli and to relieve the patient of the symptoms of tuberculosis.
7. The standard thoracoplasty fails to obliterate tuberculous pulmonary cavities in the majority of instances. Further resections

of ribs are unsatisfactory and ineffectual in completely eradicating cavities on account of the protection of the semi-obliterative para-vertebral groove; reoperated thoracoplasties are difficult and dangerous, at the same time offering no better prospect of closing cavities.

8. The inability to obliterate cavities by means of thoracoplasty and thereby require a patient to undergo a dangerous operation in vain is a serious drawback.

9. Unroofing offers the only chance of closing cavities after thoracoplasty has proved inadequate, but it leaves behind bronchial fistulae. This procedure is more applicable to the treatment of residual cavities after the standard method of performing thoracoplasty; to the checking of severe and recurrent pulmonary hemorrhages and when it is desired to drain a cavity without sacrificing any normal lung parenchyma, as in cases of advanced bilateral involvement or in the presence of mild lung cavities which would require the loss of an entire lung for closure by thoracoplasty.

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## DISCUSSION.

DR. ROBERT T. MILLER: This is a very interesting paper, and I think it is a beautiful example of what may be accomplished under consistency of conditions, materials concentrated, personnel permanent, and no pressure brought to bear such as we are constantly subjected to in civilian hospitals. That allows the work to proceed in a logical, orderly fashion towards developing the situation.

I don't know how long a period of time this work covers, but it is certainly true that it represents a direct, logical attack upon the problem, proceeding in an orderly fashion step by step.

As to the closure of subclavicular cavities, as the cases were studied the advantages of it became more and more evident. This was met firstly by an anterior pneumolysis which at first seemed to be a radical thing. The practice was, however, to pack in that lung with some foreign body. Up to that point the thing proceeded in a direct and logical fashion. Then there were added complications, and it was the sensible meeting of those complications apparently that led to the matter of unroofing the cavities. Paraffin packings became infected; they had to be opened. The abscess was then found open. So, instead of meeting it halfway by a small drainage, the thing was unroofed. It was thrown wide open and then the heliotherapy followed.

As Colonel Bruns said, this resulted, I imagine to their surprise, in the healing of a good many of these cases. But they had a long drawn out convalescence. It was not devoid of complications as to the operative technique. They have been able to overcome that by simplifying the operation; nevertheless there is the tendency, almost a certainty, of a permanent bronchial fistula remaining. A person with a permanent bronchial fistula is in a sense handicapped, though not tremendously so; nevertheless they are objectionable things. Therefore there came the effort to overcome that, and it seems to me the significance of this paper is, in spite of its title, more in the presentation of a technique whereby cavities may be collapsed by a combination of thoracoplasty and really an extensive widespread pneumolysis carried out posteriorly rather than anteriorly as a means of curing the difficulty. I think the results were that twelve were helped without any operative mortality, and in every instance the cavity was closed.

For those of you who have followed the surgery of pulmonary tuberculosis, I know you will understand that this is a major accomplishment. It took a great deal of courage, no doubt, to deliberately undertake the unroofing of tuberculous abscesses—cavities—in the lung. The mortality figures in that group of 22 cases are a formidable mortality rate. Nevertheless, if one stops to consider the fact that all of these people are doomed to death within two or three years on a statistical basis, it is not fair to compare those figures with death, but rather with life. Instead of losing nine cases you save thirteen cases, which is a much fairer way of looking at the thing, it seems to me. If they are all going to die, and we save thirteen, it is a creditable thing. If one falls into the

habit of mind of saying, "We have operated 22 patients and nine of them died," the operation will be condemned, of course. It seems to me that is an unfair way to look at the situation. Nevertheless, the significance of the paper, I feel, lies rather in the development and presentation of technique which allows apparently complete closure of the stubborn apical cavity, and closure by an operative technique in which in twelve cases up to date there has been no mortality whatsoever.

There is another phase of the thing that impressed me, and that is this: a good many of us, I think, have fallen into the habit of regarding the surgery of pulmonary tuberculosis as a thing which is fixed, static.

We present pneumothorax, we present various types of chronic nerve block, we present thoracoplasty, and that is the end of it. It is a conventionalized thing in the minds of a great many people. The actual state of affairs is that it is anything but conventionalized. The operations are modified. They are combined in various ways. We meet this case in one way and another case in another way. The thing is in a state of flux all the time, and even now, in spite of the papers we present, nobody, I believe, has a routine of treatment by which he can answer a question, "What do you do with that case?" and "What do you do with this case?" In other words, this whole matter is a difficult thing, it is a large field. Instead of being a small field, requiring little experience, I think what is needed is to show that the future of this work, the surgery of pulmonary tuberculosis, is tremendous. It is my personal belief that those who are living now are seeing merely the beginning of it. I think the younger men coming on surgery will in the course of the next fifteen or twenty years see a tremendous development in this field, and the development is coming through just such work as this.

Those of us who are working in civil hospitals, most of us to say the least, are under handicaps and I think it behooves everybody interested in this thing to point that out as often as we can. It is impossible for the casual operator to do this work and to do it satisfactorily. It is one of the most difficult types of surgery. Its development is dependent upon concentration of material, consistency of personnel, and enthusiasm and courage to go ahead with the different work. One cannot carry that out without suitable opportunity for those advantages being afforded.

It is my personal belief again that each civil hospital which ascribes to a standard position in its community will be forced to establish a service where this work can be concentrated and where opportunity can be given to those who are interested in it to carry on and emulate the work which is now being carried on in Denver.

I wish to congratulate the men who have been working at that clinic on the presentation of this paper and the work that it shows.

DR. JAMES BURNS AMBERSON, JR.: I should like to present another form of collapse therapy which has not been mentioned in this particular meeting, first because it may be of interest; second, in order to discover what the experience

of the members of the Association has been with it. I refer to scalenotomy in connection or in combination with phrenic neurectomy.

There is only one report in the literature which I can now recall, which appeared last July, on scalenotomy, but it so develops about eighteen months ago Acock, of Baltimore, in conversation with Wells, of Saranac, made some mention that the bisection of the scalenus muscle with a depression of the first rib might add to collapse of the apex.

When Acock got back to Baltimore and mentioned it to me, it appealed to me. Without knowing what the results would be, we operated several cases. We did this not only to satisfy ourselves that there was something to it, but, after all, we have to keep in mind that any collapse therapy secures its beneficial results through two factors: first, collapse, and second, immobilization, so any immobilization of the chest wall, any increase in lung rest will be beneficial.

The first thing that we did was to anesthetize a dog, and made an exposure of the ribs and intercostal muscles and observed the rhythmical, symmetrical movement during respiration. Then the splenius muscles were cut, and immediately the operated side retracted. The point of attachment of the first rib being severed when the intercostal muscles contracted, instead of the ribs moving upward and increasing the diameter of the chest, they actually depressed themselves and decreased the volume of the lung.

The second thing that was done was to secure a fresh cadaver and to cut away the chest below the level of the third rib and remove the lung. Diachylon plaster was then molded up into the apex, the mold removed, then the splenius muscles were cut, and another mold was made. Then immediately the difference in capacity of the apex is perfectly obviously estimated. We estimated it by displacement of water, and we found in this particular instance the apex of the lung had decreased in volume actually 40 per cent.

We have combined this with phrenic neurectomy. It appeals to us that the immobilization of the upper chest by scalenotomy combined with phrenic neurectomy may be of value. I have had forty-odd patients operated on in this manner in the last year. I believe that it is superior to phrenicectomy alone, and I further believe that further loss of mobility may be obviously increased by this simple procedure. The muscles are cut through the same operative wound through which the nerve is removed.

COLONEL COOPER: I do not believe that mention of the point raised by the second speaker has been made in this paper. However, I do know they have done scalenotomies along with phrenicectomies, and I don't believe that it has impressed them so much yet. Of course it was only started something like a year ago, but what will be the ultimate result of that Colonel Bruns did not mention. I cannot speak personally for Colonel Bruns, nor have I been able to follow up all of the cases of scalenotomies, but I believe that perhaps 10 or 20 of them had not impressed us a great deal clinically, though it sounded awfully good. Now, whether it will turn out to be a good thing or not I don't know, but we are trying it out.

PRESIDENT HAMMAN: I would like to express to you, Colonel Cooper, the thanks of the Association for presenting Colonel Bruns' paper in so interesting a manner.

I should also like to express the appreciation of the Association to Dr. Robert Miller for coming down and commenting in such an interesting way on Dr. Bruns' paper.

Finally, I understand that Colonel Bruns was quite ill last week, and if it meets with the approval of the meeting, I will entertain a motion that the Secretary be instructed to send a telegram from the Association, as a whole, expressing our sympathy and our regret that Colonel Bruns could not come to the meeting.

DR. JAMES ALEXANDER MILLER: I so move.

(The motion was seconded, put to a vote, and was unanimously carried.)

PRESIDENT HAMMAN: You are so instructed, Mr. Secretary.